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Application of Probit Model to Assess the Adaptability of Agricultural Technologies in Millet Farming Based on Soil Types in Chadakori Commune of Maradi Region, Niger

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Abstract

Millet is a crucial staple crop in Niger, yet its cultivation faces challenges from soil degradation and declining fertility. Effective agricultural technologies are essential for sustainable soil fertility management and improved millet productivity. This study evaluates the adaptability of farm technologies on millet farming across different soil types in Chadakori commune, Maradi region, Niger, using a probit model. Data were collected through semi-structured interviews with 250 farmers via the Kobo Collect application. STATA software was used for analysis. Results reveal that compost technology significantly enhances millet yields on loamy soils at a 1% probability threshold ($p < 0.01$). However, simple and multifunctional half-moons on sandy soils show negative effects ($p < 0.01$, and $p < 0.05$, respectively). These findings highlight the need for specific technological interventions in soil. Adaptive soil management strategies can enhance agricultural resilience and productivity, contributing to sustainable land management practices. This research offers practical recommendations for policymakers and development organizations to tackle soil degradation challenges and support millet farming systems in Niger.

Keywords

Technologies adaptability; Probit model; Soil types; Chadakori; Maradi; Niger

1. Introduction

Millet is extensively cultivated in Niger and is among the most practised staple crops (Rabo *et al.*, 2024). However, soil degradation poses a significant threat to this production, making soils infertile. According to Mahamadou *et al.* (2023), over 100,000 hectares of arable land in Niger are affected by this deterioration annually, in the face of rising demand for agricultural products. This degradation makes agricultural production challenging, as emphasized by Coulibaly *et al.* (2022). Agricultural yields remain generally unsatisfactory due to progressive soil impoverishment (Abdoul Habou *et al.*, 2016). Despite these challenges, farmers persist in cultivating less fertile lands due to declining soil fertility, scarcity of arable land, and population growth (Nassirou Ado et *al.*, 2021).

The Maradi region is known for its strong millet production capacity, accounting for 20% of the national production (World Bank Group, 2023).

Despite its significant contribution to the regional and national economy, millet production in the Maradi region faces several constraints, including population growth and climate challenges. In 2023, the World Bank reported a 17% land degradation rate in the Maradi region due to excessive natural resource exploitation. In the Chadakori commune, the depletion of natural resources for subsistence purposes has heightened competition among resource users. Urgent measures are needed to address these issues. In this context, the Rome-based Agencies (RBA) program, a collaboration among three UN agencies (FAO, IFAD, and WFP), has developed agricultural technologies for soil fertility management in Chadakori. It primarily includes simple and multifunctional half-moons, Zaï pits, assisted natural regeneration, composting, and mulching. This program aims to enhance resilience among vulnerable communities living in fragile ecosystems prone to shocks while promoting local adaptation to the impacts of climate change (AREN, 2022). However, according to (Mahamadou *et al.*, 2023), despite the use of innovative approaches and promising initiatives, achieving the goals of degraded land restoration and sustainable natural resource management requires ongoing efforts.

The restoration of degraded agricultural lands through innovative technologies requires an in-depth understanding of the appropriate technology type for each soil type and its positive impact. This research evaluates, through the application of the probit model, the adaptability of agricultural technologies on millet production according to soil types in the Chadakori commune. It will provide essential information to policymakers and structures involved in the restoration of agricultural lands, emphasizing the importance of selecting and applying agricultural technologies based on specific soil types. Conducting a rigorous evaluation using the probit model, will highlight the differentiated impacts of technologies on millet production, thus providing a solid basis for more effective and sustainable interventions. This knowledge will enable the optimization of soil fertility management strategies, thereby promoting more resilient and productive agriculture.

2. Materials and Methods

2.1. Study Area

This study was conducted in the rural commune of Chadakori, located 18 km north of Maradi, covering an area of 1756 km². Chadakori was selected due to a pilot project for the restoration of degraded agropastoral lands by the RBA program in 2018, due to its high vulnerability to climate change (WFP, 2019). The project specifically targets five sites in the commune, prioritizing beneficiaries according to a three-category vulnerability classification (highly vulnerable, vulnerable, and less vulnerable) (AREN, 2022). The commune of Chadakori is also an agropastoral zone, which facilitates the use of organic manure for compost production for effective soil fertility management. The villages included in the study integrate the six technologies of the RBA program, while the respondents, trained in these technologies, were randomly selected to ensure equitable representation in the survey.

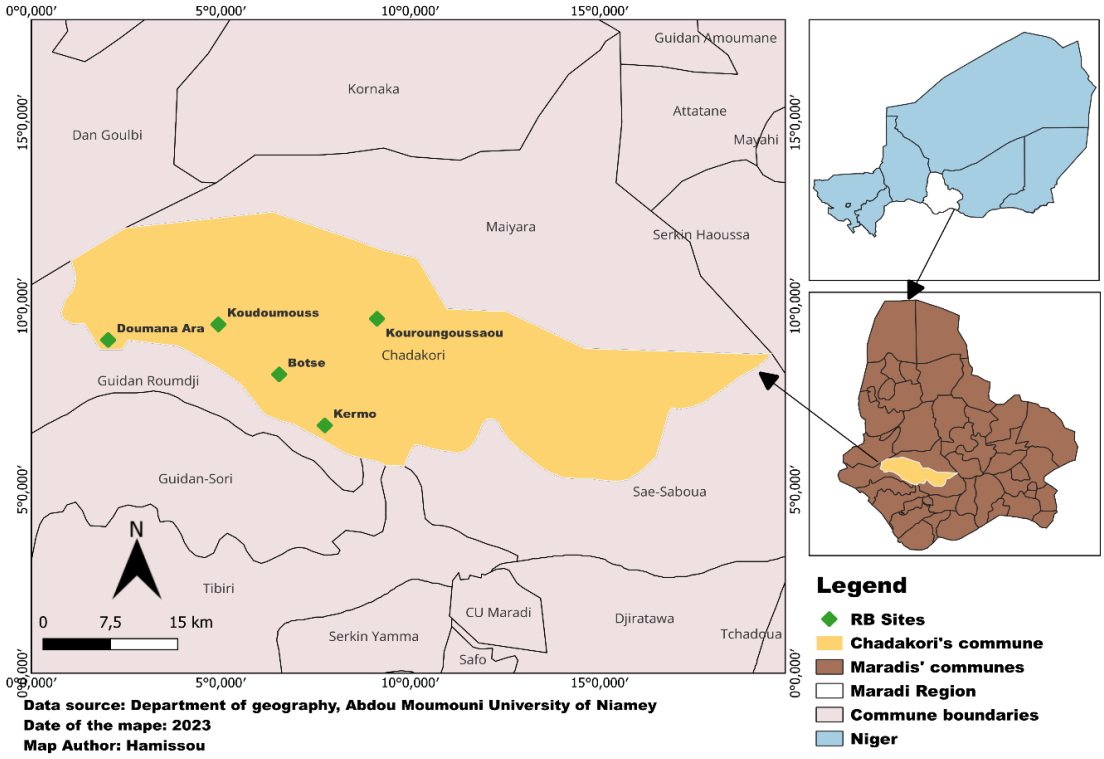

Figure 1: Map of the study area

2.2. Sample Size Calculation

A sample of 250 farmers from twelve (12) villages distributed across five (5) sites was selected. The sample size was determined first based on the five (5) sites chosen according to the criteria of agricultural technologies, and then on the 12 villages within the selected sites (Table 1). There are various methods for calculating sample size based on the study objectives. However, for this research, we chose to use a standard formula for calculating sample size in survey studies involving a finite population, as proposed by Etikan and Babatope (2019). The formula is as follows:

$$n = \frac{N * X}{N + X - 1}$$

Where $X = (Za/2^2 * P (1 - P)) / MOE2$
n = Sample size;
P = Sample proportion;
MOE = Margin of error;
N = Population of the sample

Z-(α/2) corresponds to the critical value of the normal distribution for an α/2 (for a 95% confidence level, where α is 0.05 and the critical value is 1.96). Table 1 below provides an overview of the sites and villages, as well as the number of farmers surveyed per village.

2.3. Description of the probit model

In this study, soil adaptability refers to its capacity to support agricultural technologies such as simple and multifunctional half-moons, Zaï holes, assisted natural regeneration, compost, and mulching to improve soil fertility and increase

yield. To analyze the adaptability of these technologies, this study uses the Probit model, which has proven effective in similar studies, such as those by Ousséni (2017), Oloumilade and Yabi (2019) and Bouinzemwendé *et al.* (2020). Several authors have highlighted the advantage of the Probit model over the Logit model, particularly because it provides positive probabilities (Etoundi and Dia, 2008) and makes it easier to handle data (HURLIN, 2003). Additionally, a comparative study of two models (Logit and Probit) using simulations showed that the Probit model fits better for small sample sizes (40, 100, 250), while the Logit model is more suitable for larger samples (500 and 1,000) (Cakmakyapan and Goktas, 2013). Since the sample in this study is small (250), this justifies the choice of the Probit model for analysis.

Table 1: Study Sampling

Commune of Chadakori		
Sites	*Villages*	*Number of farmers surveyed*
Kouroungoussaou	Kouroungoussaou	25
	Kouka Biyar	32
	Zoumba	7
Kermo	Kermo	28
	Guidan Magagi	31
Botsé	Botsé	12
	Kankaré Wagé	24
Koudoumous	Koudoumous	15
	Alfari	23
Doumana Ara	Doumana Ara 1	16
	Doumana Ara 2	13
	Doumana Dan Badi	24
Total	12	250

3. Results

3.1. Adaptability of Agricultural Technologies based on Soil Types

The results of the probit model used to assess the adaptability of innovative soil fertility management technologies are presented in the table below (Table 2). The estimated model is globally statistically significant at the 1% level (p = 0.00). Thus, six (6) agricultural technologies, namely simple and multifunction half-moons, Zaï, Assisted Natural Regeneration (ANR), compost, and mulching, were used to evaluate their adaptability across three soil types.

3.2. Correlation between Innovative Technologies and Soil Types

Table 3 below presents the correlation between soil types and agricultural technologies. The analysis of the correlation results shows that there is a positive relationship between simple half-moons and loamy soil. There is also a positive correlation between multifunction half-moon clayey soils and loamy soils. Similarly, there is a positive relationship between sandy soils and ANR, and finally

between compost and loamy soils. This positive correlation suggests that the higher the use of ANR, compost, and multifunctional half-moons, the more sandy, loamy, and clayey soils become fertile. However, negative correlations are observed between simple and multifunctional half-moons and sandy soils. This negative correlation indicates that the higher the use of simple and multifunctional half-moons, the more the sandy soils become less fertile.

Figure 2: Six agricultural technologies applied across three types of soils a) Zaï (AREN, 2022); b) Multifunction half-moons (ME/LCD, 2022); c) Simple half-moons (ME/LCD, 2022) ; d) Assisted Natural Regeneration (ANR) (CILSS, 2021); e) Compost (ME/LCD, 2022); f) Mulching (WOCAT, 2014).

Table 2: Adaptability of agricultural technologies on different soil types

Soil types	*Coef*	*Std. Err.*	*P-value*
Sandy soils			
Simple half-moons	-0.45	0.24	0.058
Multifunction half-moons	-0.74	0.23	0.002
ANR	0.26	0.21	0.222
Zaï	-0.36	0.19	0.061
Compost	0.4	0.23	0.091
Mulching	0.25	0.34	0.456
_cons	1.09	0.35	0.002
Loamy soils			
Simple half-moons	0.9	0.25	0.00
Multifunction half-moons	0.56	0.25	0.027
ANR	0.36	0.22	0.113
Zaï	0.18	0.18	0.323
Compost	0.77	0.23	0.001
Mulching	0.19	0.32	0.552
_cons	-1.35	0.35	0
Clay soils			
Simple half-moons	-0.09	0.3	0.749
Multifunction half-moons	0.61	0.32	**0.056**
ANR	0.39	0.25	0.114
Zaï	0.35	0.2	0.085
Compost	-0.02	0.26	0.937
Mulching	0.79	0.52	0.128
_cons	0.32	0.38	0.395
	Sandy soils	*Loamy soils*	*Clay soils*
Number of observation	250	250	250
Log-likelihood	-142.28	-149.46	-104.34
Meaning of the model	LR chi^2 (6) = 42.14	LR chi^2 (6) = 45.71	LR chi^2 (6) = 11.14
	Prob > chi^2 = 0.00	Prob > chi^2 = 0.00	Prob > chi^2 = 0.08
Pseudo R^2	0.1290	0.1326	0.0507

3.3. Adaptability of Agricultural Technologies on Soil Types

Overall, figure 2 presents the results of soil adaptability on agricultural technologies based on farmers' responses. The analysis results revealed that the six agricultural technologies are adaptable to the three types of soils but to varying degrees. Sandy soils are the most suitable for innovative technologies (84%), followed by clayey soils (64%) and loamy soils (54%). This implies that sandy soils are the most predominant in the Chadakori commune.

Table 3: Correlation between agricultural technologies and soil types

Innovative technologies	*Clay soils*	*Loamy soils*	*Sandy soils*
Simple half-moons	0.031	0.332	-0.311
Multifunctional half-moons	0.105	0.273	-0.340
ARN	0.053	-0.068	0.216
Zaï	0.097	-0.003	-0.069
Compost	-0.029	0.146	-0.040
Mulching	0.084	0.050	0.026

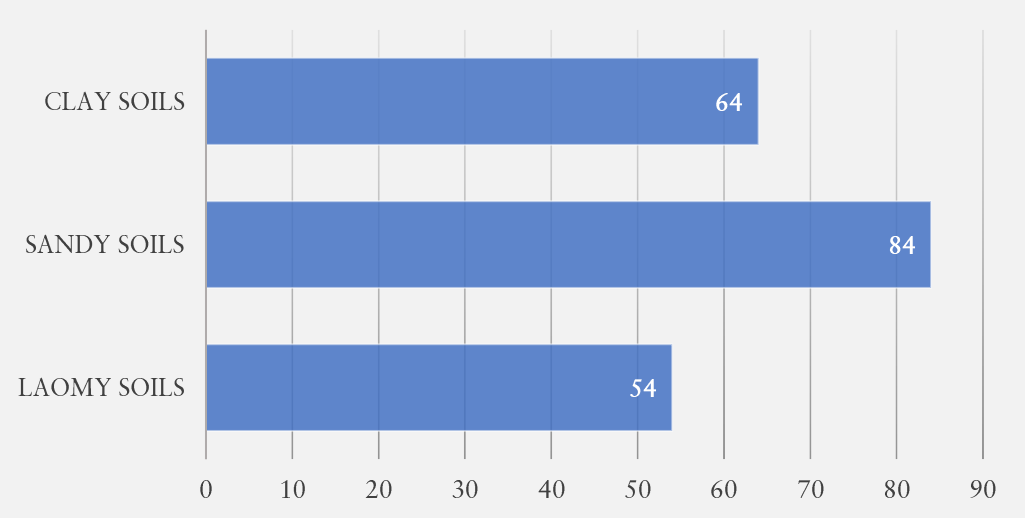

Figure 2: Soils suitable for different types of technology (%)

4. Discussion

The study used data collected from farmers in 12 villages within the study area. A simple probit regression was used to analyze the adaptability of agricultural technologies based on soil types. The results revealed that simple half-moons (α = - 0.45; p = 0.05), multifunction half-moons (α = -0.74; p = 0.002) and Zaï (α = - 0.36; p = 0.06) are significantly and negatively adapted to sandy soils, with a threshold probability of 5% and 10%. However, simple half-moons (α = 0.9; p = 0.00), multifunctional half-moons (α = 0.56; p = 0.02) and compost (α = 0.77; p = 0.00) are significantly and positively adapted for sandy soils at a probability threshold of 1% and 5%. Similarly, multifunctional half-moons (α = 0.61; p = 0.05) are significantly and positively adapted to clay soils at a probability threshold of 5%. For correlation analysis, positive correlations have been observed between simple half-moons and loamy soils, multifunctional half-moons and clay and loamy soils, assisted natural regeneration and sandy soil and lastly between compost and loamy soils. Oppositely, a negative correlation between simple and multifunctional half-moons has been identified between sandy soils. Overall, sandy soils are the most suitable for innovative technologies (84%).

Simple and multifunctional half-moons, Zaï and compost are significantly but negatively adapted to sandy soils. However, the multivariate probit model is based on the probability principle. This leads to the conclusion that, likely, the

innovative technologies (simple and multifunctional half-moons, Zaï and compost) are not suited to sandy soils, suggesting that an increase of 1% will result in a probability of a decrease in soil fertility of 45%, 74%, 36% and 40% respectively. According to the respondents, simple and multifunctional half-moons are made on degraded, notched or gullied soils. This statement is similar to that of Nassirou Ado *et al.* (2021), who claim that multifunctional half-moons are made on initially encrusted and uncultivated land. As for Zaï and compost, they quickly disappear long before the first rains fall when combined (Zaï and compost), said the respondents.

On the other hand, simple and multi-function half-moons and compost are significantly and positively adapted to loamy soils. Probably, the innovative technologies (simple and multifunctional half-moons, compost) are adapted to loamy soils, suggesting that an increase of 1% will result in a 90%, 56% and 77% probability of increasing soil fertility. Likewise, for Zaï, a 1% increase in soil fertility would result in a 35% increase in clay soil fertility. Such results are in line with respondents' views that simple and multifunctional half-moons, Zaï and compost prefer to be made on loamy and clayey soils.

Sandy soils can support Zaï plus compost technologies, but at different times to loam and clay soils. Respondents said that Zaï plus compost could be applied to sandy soils two months before the start of the season, and four months on loam and clay soils. The aim is to reduce the risk of holes disappearing due to wind erosion. Unlike silty and clayey soils, we prefer wind erosion to gradually deposit sand in the holes containing the compost. This is a real advantage for degraded and encrusted soils. Respondents explained that depositing sand in the holes not only preserves the quality of the compost but also conserves moisture so that even in the event of drought, seedlings won't suffer water stress. Generally speaking, sandy soils are the best adapted to innovative technologies in the five sites studied. The adaptability of sandy soils to innovative technologies in Chadakori depends on the type of soil, which is predominantly sandy.

To categorize the soil types on which innovative technologies are adapted, farmers used their endogenous knowledge. They refer to morphological criteria such as colour, texture and structure to characterize soil types. Colour is identified visually, texture and structure by tactile sensation. Such knowledge is in line with the work of (Kissou *et al.*, 2018), according to whom Fulani farmers used their local knowledge to characterize soils by texture. The same is true of farmers in Gothèye and Tagazar, who appreciate the soil fertility indicator thanks to its dark colour (Biga *et al.*, 2021).

The results of the correlation analysis revealed a positive relationship between ANR and sandy soils, compost and silty soils, and multifunctional half-moons and clay soils. This positive relationship means that the greater the use of ANR, compost and multifunctional half-moons, the more sandy, silty and clay soils become fertile. Respondents rank ANR and compost as the benchmark technologies for soil fertility management. They enable a considerable increase in millet yield per hectare and the regeneration of ecosystems lacking good vegetation cover.

In all soil types, mulching and assisted natural regeneration have not shown any significance in terms of adaptability. This insignificance can be explained by the fact that munching is not at all used as a technology to restore soil fertility compared to other technologies. In the study areas, only a few farmers conventionally use millet or sorghum stalks to restore their soil. However,

mulching faces several challenges that prevent farmers from using it effectively. First, villagers or people from surrounding areas collect these stalks as soon as possible for cooking or selling. Second, the Chadakori Commune is an agro-pastoral zone, making the adoption of mulching technology difficult. According to one respondent, he cannot leave millet or sorghum stalks in the field when he has livestock to feed. Beyond these challenges, there is a significant gap in the promotion of mulching technology by extension services in this commune compared to others. Assisted natural regeneration depends on the tree species that support natural regeneration and their ability to improve soil health. In Niger, common trees used for this technique in millet farming include *Acacia albida, Piliostigma reticulatum, Guiera senegalensis*, and *Combretum micranthum*. Without these trees on the three soil types, applying assisted natural regeneration becomes challenging. Additionally, farmers face difficulties as young shrubs are often cut by villagers, bushers, or herders for cooking, selling, or feeding animals.

5. Conclusion

The study evaluated the effects of agricultural technologies in improving soil fertility management according to soil types. Six (6) technologies were used to evaluate their adaptability based on three soil types including sandy, clay and loamy soils. The results indicated that some of the technologies are significant but negatively and positively adapted to soil types. These include simple and multifunctional half-moons, and Zaï significantly but negatively adapted to sandy soils. The main objective of these technologies is to improve soil fertility in millet farming. With a negative coefficient, these technologies contrarily decrease the soil fertility due to the soil nature. Simple and multifunctional half-moons and Zaï are made on degraded, notched or gullied soils. However, simple and multifunctional half-moons and compost are significantly and positively adapted to loamy soils, showing their capacity to improve soil fertility. Similarly, multifunctional half-moons can improve soil fertility because they are significantly and positively adapted to clay soils. These results are confirmed by correlation analysis indicating a positive relationship between multifunctional half-moons clayey soils and loamy soils, and negative correction between simple and multifunctional half-moons and sandy soils. The positive correlations between technologies and soil types mean that the greater the use of these technologies, the more the soil becomes fertile. For the negative correlations, the greater the use of these technologies, the more the soil fertility decreases. Overall, neither mulching nor assisted natural regeneration technologies are well-suited to any of the three soil types. Mulching is considered a local technology and is not widely used, as millet stalks are primarily used for cooking, housing, and animal feed. Assisted natural regeneration, on the other hand, requires extensive field monitoring to prevent the cutting of young shrubs by villagers, bushers, or herders for cooking, selling, or feeding animals.

These findings underscore the importance of selecting appropriate technologies based on soil types to enhance agricultural productivity and resilience. Sustainable land restoration requires context-specific interventions to improve soil fertility and promote biodiversity. Policymakers and development organizations should take into consideration what types of technology and their effect in improving soil health based on soil types. From a future perspective, it would be necessary to investigate the adaptability of these technologies on these

types of soils through soil sampling, laboratory analysis and millet yield assessment to confirm their adaptability.

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7. References

Abdoul Habou, Z., Boubacar, M.K. and Adam, T. (2016). Agricultural production systems in Niger facing climate change: Challenges and perspectives. *International Journal of Biological and Chemical Sciences*, 10(3): 1262–1272. DOI: https://doi.org/10.4314/ijbcs.v10i3.28.

AREN (2022). Annual report of rural development activities (Final report from January to December 2022. Narrative Report REF/WFP: N°15/AREN/2022. Maradi: p. 11.

Biga, I., Mamoudou Boubacar, M., Amadou Oumani, A. and Ali, M. (2021). Farmers' Perceptions and Strategies for Soil Fertility Management in the Tillabéry Region of Western Niger. *International Journal of Advanced Research*, 9(4): 740–751. DOI: https://doi.org/10.21474/IJAR01/12760.

Bouinzemwendé, P.M., Ouango, S.M., Jean, O., Gaspard, V., Dehou, D., Papaoba, S.M. and François, L. (2020). Socio-Economic Determinants of Soil Degradation and the Adoption of Soil Fertility Management Technologies Based on Farmers' Perceptions in the Cotton-Growing Areas of Burkina Faso. *Asian Journal of Science and Technology*, 11(6): 11003–11011.

Cakmakyapan, S. and Goktas, A. (2013). A comparison of binary logit and probit models with a simulation study. *Journal of Social and Economic Statistis*, 2(1): 1–17.

CILSS (2021). Sheet 18: Assisted Natural Regeneration (ANR) – Best Resilient Practices. Available online at: https://pratique-resiliente.net/2021/08/03/fiche-18-regeneration-naturelle-assistee-rna/ (Accessed on 30 June 2023).

Coulibaly, K., Baggnian, I., Zakou, A. and Nacro, H.B. (2022). Farmers' perception of water and soil conservation techniques and soil defense and restoration (CES/DRS) in West Africa: Case of Burkina Faso and Niger. *European Scientific Journal,* 18(27): 121. DOI: https://doi.org/10.19044/esj.2022.v18n27p121.

Etikan, I. and Babatope, O. (2019). A Basic Approach in Sampling Methodology and Sample Size Calculation. *MedLife Clinics*, 1(2): 050–054.

Etoundi, S.M.N. and Dia, B.K. (2008). Determinants of the adoption of improved varieties of Maize in Cameroon: case of cms 8704. MPRA *(Munich Personal RePEc Archive)*: 19.

HURLIN (2003). Econometrics of Qualitative Variables - Course Handout. p.56.

Kissou, R., Gnankambary, Z. and Nacro, H.B. (2018). Local Classification and Land Use in the Sahelian Zone of Burkina Faso. *International Journal of*

Biological and Chemical Sciences, 12(1): 610. DOI: https://doi.org/10.4314/ijbcs.v12i1.46.

Mahamadou, A., Ismaël, A.B. and Garba, I. (2023). Analysis of land occupation dynamics and economic outcomes of sustainable land management in the Tillabéri Region of Niger. *International Journal of Innovation and Applied Studies*, 39(2): 595–607.

ME/LCD (2022). Best Practices for Sustainable Land Management (SLM) in Niger. Recueil de fiches techniques. Available online at: https://niger-gdte.net/books/1-techniques-mecaniques-de-conservation-des-eaux-et-des-solsdefense-et-restauration-des-sols (Accessed on 30 June 2023).

Nassirou Ado, M., Sani Moussa, M. and Ambouta, H.K. (2021). Effects of Multifunctional Half-Moons on Sorghum Production in West Africa: Case of the Tahoua Region in Niger. *European Scientific Journal* 17(34): 112. DOI: https://doi.org/10.19044/esj.2021.v17n34p112.

Ousséni, B. (2017). Farmers' Perception and Socio-Economic Determinants of the Adoption of Microdosing Tested on Soybean *(Glycine max L.)* and Maize *(Zea mays L.)* in the Nahouri and Sissili Provinces of Burkina Faso. Université NAZI BONI (UNB). p. 78.

Rabo, Y., Sani, I.S. and Mahamane, A. (2024). Effects of Zaï and number of plants per pit on millet growth and yield in the Sahelian environment of Niger. *Revue Marocaine des Sciences Agronomiques et Vétérinaires*, 12(1): 7–12. DOI: https://doi.org/10.5281/ZENODO.10792667.

WFP (2019). International Symposium on Agricultural Innovation for Family Farmers: Unlocking the Potential of Agricultural Innovation to Achieve the Sustainable Development Goals. Annual Report – Year 2. Rome, Italy, p. 126.

WOCAT (2014). Mulching [Niger], wocat.net. Available online at: https://qcat.wocat.net/fr/wocat/technologies/view/technologies_1222/ (Accessed on 1 July 2023).

World Bank Group (2023). Niger Country Environmental Analysis. World Bank Group, p. 96. Available online at: https://www.worldbank.org (Accessed on 13 February 2025).

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	Author 1	Author 2
Conceived and designed the research or analysis	Yes	Yes
Collected the data	Yes	Yes
Contributed to data analysis & interpretation	Yes	Yes
Wrote the article/paper	Yes	Yes
Critical revision of the article/paper	Yes	Yes
Editing of the article/paper	Yes	Yes
Supervision	Yes	Yes
Project Administration	Yes	Yes
Funding Acquisition	Yes	Yes
Overall Contribution Proportion (%)	50	50

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Research involving human bodies or organs or tissues (Helsinki Declaration)
The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

Research involving animals (ARRIVE Checklist)
The author(s) solemnly declare(s) that this research has not involved any animal subject (body or organs) for experimentation. The research was not based on laboratory experiment involving any kind animal. The contexts of animals were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of ARRIVE does not apply in cases of this study or written work.

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The author(s) solemnly declare(s) that this research has not involved Indigenous Peoples as participants or respondents. The contexts of Indigenous Peoples or Indigenous Knowledge were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or prior informed consent (PIC) of the respondents or Self-Declaration in this regard does not apply in cases of this study or written work.

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through literature review. Thus, during this research the author(s) obeyed the principles of the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.

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